Designing, Implementing, and Monitoring Fully Protected Zones: An Example from the Florida Keys National Marine Sanctuary

Brian D. Keller, Joanne M. Delaney *and* ***Billy D. Causey***
Florida Keys National Marine Sanctuary

Abstract
The Florida Keys National Marine Sanctuary (FSNMS) is a 9,950-km^2 marine protected area managed by the U.S. National Oceanic and Atmospheric Administration and the State of Florida. A comprehensive management plan was implemented in 1997 to protect and conserve marine resources of the Florida Keys, which include mangrove, seagrass, and coral reef habitats and their associated communities. One innovative aspect of sanctuary management is a network of 24 fully protected zones that are designed to protect biodiversity and sensitive habitats, reduce user conflicts, and lessen concentrated impacts to marine organisms at heavily used reefs. An ongoing monitoring program is designed to determine effects of "no-take" protection on heavily exploited fishes and invertebrates, benthic communities, and human activities and perceptions. Data on the abundance and size of fish, spiny lobster, and queen conch; algal cover; coral cover, diversity, and recruitment; and zone usage are collected from fully protected zones and adjacent reference sites. Preliminary reports indicate increases in the number and size of certain heavily exploited species such as spiny lobster and some fish species within fully protected zones. Slower-growing benthic species such as corals and sponges have not shown significant changes within protected areas, possibly because of the short period since implementation of the zoning plan.

Introduction
The only coral reef tract off the continental U.S. is located in the Florida Keys, from south of Miami to the Dry Tortugas (Figure 1). The Florida Reef Tract comprises one of the largest coral reef systems of its type in the world, arching 356 km east and south of the Keys at a distance of 4.8 to 11.3 km offshore. Because the Upper and Lower Keys are protected from direct flow of water from the Gulf of Mexico, they are considered to have greater reef development than the Middle Keys (Robbin 1981; Shinn et al 1989). All but the northernmost extent of the Florida Reef Tract lies within the boundaries of the Florida Keys National Marine Sanctuary (FKNMS or Sanctuary). The Sanctuary was designated in 1990 to protect and conserve nationally significant biological and cultural marine resources of the area, including critical coral reef habitats.

The Florida Keys National Marine Sanctuary encompasses 9,950 km^2. Over half of the sanctuary is in state of Florida territorial waters; the rest (42%) is in federal waters. Overall, the reef system along the Florida Keys consists of several distinct habitat types including nearshore patch reefs, mid-channel reefs, offshore patch reefs, seagrass beds, back reefs/reef flat, hard-bottom communities, bank or transitional reefs, intermediate reefs, deep reefs, outlier reefs, and sand/soft bottom areas. One of the most noticeable features of the bank reefs of the Florida Keys is seaward-facing spur-and-groove formations, constructional features formed in part by wave energy (U.S. DOC 1996). Tops of spurs were composed mainly of *Acropora palmata*, especially at depths less than 5 m, until the demise of acroporids throughout much of the Caribbean region in the early 1980s. Grooves contain carbonate sand and reef rubble. These features may extend 1 to 2 km off the main reef, from depths of 1 to 10 m. Primary corals found in this area include the *Montastrea annularis* complex and *Montastrea cavernosa*, *Siderastrea siderea*, and *Millepora* spp. *Porites astreoides*, *P. porites*, and *Agaricia agaricites* are also common species. *Acropora cervicornis* and *A. palmata*, formerly common or dominant species at depths of 3 - 15 m, are present in very low abundance at this time. In addition to bank reefs, over 6,000 patch reefs that are circular to oval in shape lie along the Florida Reef Tract in 2 to 9 m of water.

Numerous studies have been completed that describe the inhabitants of the Florida Keys coral reef community. Over 520 species of fish have been identified from the Florida Keys overall (Starck 1968), which includes over 260 species of reef fish (Bohnsack et al 1999). Three-hundred sixty-seven (367) taxa of algae have been identified (Littler and Littler 2000), as well as 117 species of sponges (Levy et al 1996), 89 species of polychaete worms (Levy et al 1996), and 128 species of echinoderms (Hendler et al 1995). Surveys of fire corals, octocorals, stony corals, zooanthids, and corallimorpharians (false corals) found two species of fire coral, 55 species of octocoral, and 63 taxa of stony corals (U.S. DOC 1996; Levy et al 1996).

With the designation of the Florida Keys National Marine Sanctuary in 1990, the coral reef tract of the Florida Keys was afforded certain levels of protection. Oil and hydrocarbon exploration, mining, and large shipping traffic and their

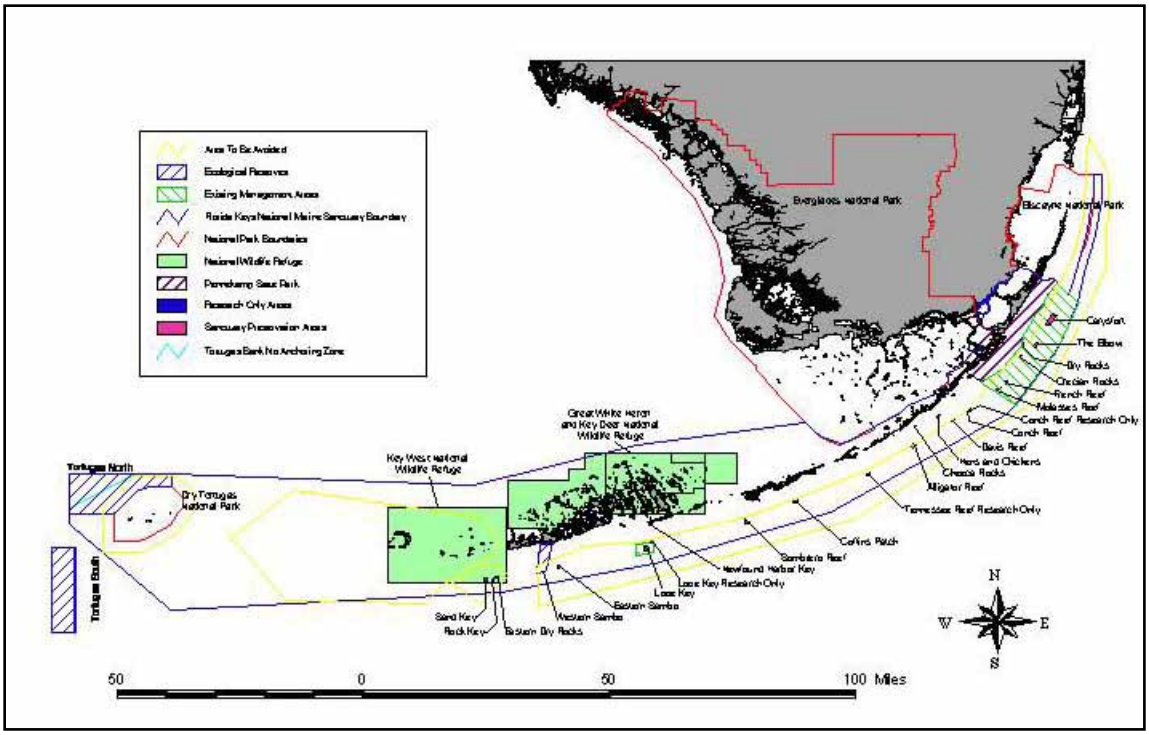

Figure 1. Map of the Florida Keys National Marine Sanctuary showing the fully protected zones (Ecological Reserves, Research-Only Areas, and Sanctuary Preservation Areas).

resulting impacts are excluded from the Sanctuary. Anchoring on corals in shallow water is prohibited, as is touching coral, collecting living or dead coral, and taking "live rock," a product of the aquarium trade. The Sanctuary has the authority to address discharges within its boundary as well as potential pollutants that originate from outside the Sanctuary, offering protection of water quality that is critical for coral reef health and vitality.

FKNMS Fully Protected Zones

In addition to Sanctuary-wide regulations that address direct and indirect impacts to coral reef resources, the creation of fully protected zones preserves specific reef areas more completely. A network of 24 fully protected zones, which cover approximately 6% of the Sanctuary but protect 65% of shallow bank reef habitats and 10% of coral resources overall, were implemented in 1997 (23 zones) and 2001 (Tortugas Ecological Reserve) (Figure 1). Lobstering, fishing, spearfishing, shell collecting, and other consumptive activities are prohibited in these areas. Most of the smaller zones (Sanctuary Preservation Areas) are located along the offshore reef tract and encompass the most heavily used spur-and-groove coral formations. The 31 km^2 Western Sambo Ecological Reserve protects offshore reef as well as all other habitats, including mangrove fringe, seagrasses, hard-bottom communities, and patch reefs. The 518 km^2 Tortugas Ecological Reserve, established in July 2001 after a three-year collaborative design and planning process (Delaney 2003), is located in the westernmost portion of the Florida Reef Tract (Figure 1). The Tortugas Ecological Reserve conserves important deep-water reef resources and fish communities unique to this region of the Florida Keys. The Reserve is also significant because it adjoins a proposed 158 km^2 Research Natural Area in the Dry Tortugas National Park, an area where shallow seagrass, coral, sand, and mangrove communities will be conserved. Together, the Sanctuary's Tortugas Ecological Reserve and the National Park's Research Natural Area protect nearshore to deep reef habitats of the Tortugas region and form the largest, permanent fully protected zone in the United States.

FKNMS Zone Monitoring Program

A monitoring program is measuring effects of these 24 fully protected zones on heavily exploited fishes and invertebrates, benthic communities, and human activities and perceptions. The Zone Monitoring Program uses a combination of academic and government scientists as well as volunteers to look at changes in ecosystem structure (species abundance and size) and function (processes such as fish grazing rates) that result from the cessation of human consumptive activities. Data on the abundance and size of fish and mobile invertebrates, macroalgal cover and biomass, changes in coral cover and diversity, coral recruitment, and zone usage are collected from inside fully protected zones and adjacent reference sites. Below are brief summaries of findings to date of the effects of fully protected zones on these parameters.

Five years of monitoring of the Sanctuary's fully protected zones indicates that some heavily exploited species exhibit differences in abundance and size between the zones and reference sites. Since protection began in 1997, there has been an increase in the percentage of legal-sized spiny lobsters in the Western Sambo Ecological Reserve (WSER), while the abundance of legal lobsters in its reference area is significantly lower (Cox et al 2003). In addition, the mean size of lobsters has been significantly larger in the WSER in both the open and closed fishing seasons. Specifically, the mean size of males on offshore patch reefs of the WSER has increased 10 mm in the last five years. Catch rates of lobsters in traps were higher within WSER than in two adjacent non-reserve areas regardless of year or fishing season (Gregory 2003). More lobsters were caught in WSER traps than in the two non-reserve areas combined. These data suggest that temporary refuge may be afforded to spiny lobsters by the large and spatially diverse reserve, WSER. In contrast, no differences in the size of legal-sized lobsters between the smaller-sized SPAs and their reference sites were detected (Cox et al 2003), suggesting that the effectiveness of reserves for spiny lobsters is a function of reserve size, location, and the type of habitat protected.

Significant density increases were noted for several exploited reef fish species in fully protected zones compared to reference sites since implementation of the zones (Bohnsack et al 2003). Mean densities of gray snapper, combined grouper species, and yellowtail snapper were greater in protected zones than at fished sites. Hogfish densities, however, remained higher in fished rather than unfished areas, perhaps because of differences in available seagrass habitat. REEF's Advanced Assessment Team calculated reef fish species richness for fully protected/reference site pairs throughout the Sanctuary (REEF 2003). In all but 4 of the 16 of the site pairs, fish species richness was greater in the fully protected sites. Examination of the abundance trends for each of 75 species between fished and unfished sites revealed no statistical differences, yet more species increased in abundance in protected than in reference sites.

During the past five years, no significant differences in populations of queen conch between fully protected and reference sites have been detected (Glazer and Delgado 2003). Conch were distributed in well-defined aggregations that are not entirely encompassed by SPAs, with the majority of adult conch in the Lower Keys, from Looe Key south to Western Sambo Ecological Reserve (Figure 1). From 2000 to 2001, a large recruitment of juvenile conch seems to have taken place throughout the Keys. Two separate teams continue to document very low abundances of sea urchins, especially the long-spined urchin (*Diadema antillarum*) (Miller et al 2003; Rosov 2003). In one study, all of the sampling locations yielded very low densities of *Diadema antillarum,* although several locations with large-sized urchins and clear effects of grazing were encountered (Miller et al 2003).

In general, the Sanctuary's coral reef monitoring projects have documented a high degree of variability over space (habitat type and region) and time for several ecosystem parameters such as coral cover, species richness, recruitment, and density of benthic invertebrates (Wheaton et al 2003; Miller et al 2003; Aronson et al 2003). No consistent differences in coral recruitment between the no-take areas and reference sites have been observed (Miller et al 2002; Ogden et al 2002; Aronson et al 2003). Juvenile coral mortality rates varied between habitats and years, which is likely due to the effect of several large storm events in 1998 and 1999 (Ogden et al 2002). Additionally, no significant differences in the percent cover of hard corals and sponges were noted between fully protected areas and reference sites (Miller et al 2002). As documented by one monitoring program, coral cover has remained consistent within no-take and reference sites, suggesting that regional influences may be affecting coral health (Miller et al 2002). Monitoring of macroalgal biomass indicates variability based on season, water depth, and region, with no major differences between no-take and reference sites noted at this time (Ogden et al 2002; Aronson et al 2003). Preliminary field experiments on algal grazing rates suggest decreased herbivory within fully protected zones, but a significant trend has not yet been established. Researchers monitoring these parameters caution that the high variability of benthic components over space and time necessitates looking at the effects of no-take regulations on a decadal time scale.

Similar to the findings for the biological components of the Sanctuary's Zone Monitoring Program, socioeconomic monitoring indicates that zone usage is highly seasonal (McClellan and Tobias 2002). Non-consumptive diving charters frequent outer reef areas, both inside and outside of the no-take zones, primarily during the summer months. Fishing activity is also highly variable, which is to be expected given the sheer number of economically important recreational and commercial fisheries in the Florida Keys. Commercial lobster fishing comprises the majority of vessel activity observed by one monitoring program. Initial data suggest compliance with no-take regulations is relatively high because little illegal use of fully protected zones has been observed (McClellan and Tobias 2002). Preliminary data on financial performance of commercial fishermen indicate that displacement from the Western Sambo Ecological Reserve did not cause short-term financial losses (Murray et al 2002). Additional socioeconomic research is underway (Leeworthy et al 2002; Smith et al 2002).

Conclusion

Coupling biological data with socioeconomic and use information is critical to assess both the ecological status of and community attitudes towards the Sanctuary's zone network. As evidenced by results after just four years, continued monitoring inside and outside of the fully protected zones is necessary before trends can be identified, particularly in slow-growing, sessile benthic organisms (Aronson et al 2003; Miller et al 2003). Nonetheless, strong responses in abundance of certain heavily exploited reef fish species (Bohnsack et al 2003) and in abundance and size of spiny lobster in the relatively large Western Sambo Ecological Reserve (Cox et al 2003) are already apparent.

Literature Cited

Aronson, R.B., M.W. Miller, S.R. Smith, T. Murdoch, and J.C. Ogden, 2003, Coral reef ecosystem process studies in the fully protected zones of the Florida Keys National Marine Sanctuary, **In**: U.S. Department of Commerce, *Sanctuary Monitoring Report 2001: An Ecosystem Report Card*, Florida Keys National Marine Sanctuary, Marathon, FL, pp.36-42. [floridakeys.noaa.gov/research_monitoring/welcome.html]

Bohnsack, J.A., D.B. McClellan, D.E. Harper, G.S. Davenport, G.J. Konoval, A.-M. Eklund, J.P. Contillo, S.K. Bolden, P.C. Fischel, G.S. Sandorf, J.C. Javech, M.W. White, M.H. Pickett, M.W. Hulsbeck, J.L. Tobias, J.S. Ault, G.A. Meester, S.G. Smith, and J. Luo, 1999, *Baseline data for evaluating fish populations in the Florida Keys, 1979-1998*, NOAA Technical Memorandum NMFS-SEFSC-427, 61pp.

Bohnsack, J.A., D.B. McClellan, D.E. Harper, J. Ault, S. Smith, G. Meester, and J. Luo, 2003, Preliminary analysis of FKNMS reef fish monitoring through 2001, **In**: U.S. Department of Commerce, *Sanctuary Monitoring Report 2001: An Ecosystem Report Card*, Florida Keys National Marine Sanctuary, Marathon, FL, pp.54-60. [floridakeys.noaa.gov/research_monitoring/welcome.html]

Cox, C., N.K. Jue, M.C. Darcy, and J.H. Hunt, 2003, Monitoring Caribbean spiny lobsters in the Florida Keys National Marine Sanctuary, 1997 – 2001. **In**: U.S. Department of Commerce, *Sanctuary Monitoring Report 2001: An Ecosystem Report Card*, Florida Keys National Marine Sanctuary, Marathon, FL, pp.71-75. [floridakeys.noaa.gov/research_monitoring/welcome.html]

Delaney, J.M., 2003, Community capacity building in the designation of the Tortugas Ecological Reserve, *Gulf Carib. Res.*, **14**:163-169.

Glazer, R., and G. Delgado, 2003, Queen conch marine reserve monitoring, **In**: U.S. Department of Commerce, *Sanctuary Monitoring Report 2001: An Ecosystem Report Card*, Florida Keys National Marine Sanctuary, Marathon, FL, pp.82-90. [floridakeys.noaa.gov/research_monitoring/welcome.html]

Gregory, D.R., 2003, Sentinel lobster fisheries project for the Florida Keys National Marine Sanctuary, January-December, 2001, **In**: U.S. Department of Commerce, *Sanctuary Monitoring Report 2001: An Ecosystem Report Card*, Florida Keys National Marine Sanctuary, Marathon, FL, pp.76-81. [floridakeys.noaa.gov/research_monitoring/welcome.html]

Hendler, G., J.E. Miller, D.L. Pawson, and P.M. Kier, 1995, *Sea Stars, Sea Urchins, and Allies: Echinoderms of Florida and the Caribbean,* Smithsonian Institution Press, Washington, DC, 390pp.

Leeworthy, B., P. Wiley, G. Johns, F. Bell, and M. Bonn, 2002, Monitoring of Sanctuary use patterns, and market and nonmarket economic values of Sanctuary resources. **In**: U.S. Department of Commerce, *Sanctuary Monitoring Report 2000*. Florida Keys National Marine Sanctuary, Marathon, FL, p.50. [floridakeys.noaa.gov/research_monitoring/welcome.html]

Levy, J.M., M. Chiappone, and K.M. Sullivan, 1996, *Invertebrate Infauna and Epifauna of the Florida Keys and Florida Bay. Site Characterization for the Florida Keys National Marine Sanctuary and Environs, Volume 5*. The Nature Conservancy, Arlington, VA, 166 pp.

Littler, D.S. and M.M. Littler, 2000, *Caribbean Reef Plants*, Offshore Graphics, Inc., Washington, DC, 542pp.

McClellan, D.B. and J.L. Tobias, 2000, Aerial survey of vessel usage and marine animal occurrences in the FKNMS, 1992 – 2000, **In**: U.S. Department of Commerce, *Sanctuary Monitoring Report 2000*. Florida Keys National Marine Sanctuary, Marathon, FL, pp.46-48. [floridakeys.noaa.gov/research_monitoring/welcome.html]

Miller, S.L., D.W. Swanson, and M. Chiappone, 2002, Rapid assessment and monitoring of fully protected zones in the FKNMS, **In**: U.S. Department of Commerce, *Sanctuary Monitoring Report 2000*, Florida Keys National Marine Sanctuary, Marathon, FL, pp.22-26. [floridakeys.noaa.gov/research_monitoring/welcome.html]

Miller, S.L., M. Chiappone, H. Dienes, and D.W. Swanson, 2003, Rapid assessment and monitoring of coral reef habitats in the Florida Keys National Marine Sanctuary: annual summary report: summer 2001 zone monitoring, **In**: U.S. Department of Commerce, *Sanctuary Monitoring Report 2001: An Ecosystem Report Card*, Florida Keys National Marine Sanctuary, Marathon, FL, pp.43-50. [floridakeys.noaa.gov/research_monitoring/welcome.html]

Murray, T., M. Shivlani, and B. Leeworthy, 2002, Socioeconomic monitoring of commercial fishing panels, **In**: U.S. Department of Commerce. *Sanctuary Monitoring Report 2000*, Florida Keys National Marine Sanctuary, Marathon, FL, p.49. [floridakeys.noaa.gov/research_monitoring/welcome.html]

Ogden, J.C., R.B. Aronson, M.W. Miller, S.R. Smith, and T. Murdoch, 2002, Dynamics of coral reef benthic communities, **In**: U.S. Department of Commerce, *Sanctuary Monitoring Report 2000*, Florida Keys National Marine Sanctuary, Marathon, FL, pp.19-21. [floridakeys.noaa.gov/research_monitoring/welcome.html]

Reef Environmental Education Foundation (REEF), 2003, Volunteer reef fish monitoring in the Florida Keys National Marine Sanctuary, **In**: U.S. Department of Commerce, *Sanctuary Monitoring Report 2001: An Ecosystem Report Card*, Florida Keys National Marine Sanctuary, Marathon, FL, pp.61-70. [floridakeys.noaa.gov/research_monitoring/welcome.html]

Robbin, D.M., 1981, Subaerial $CaCO_3$ crust: a tool for timing reef initiating and defining sea level changes, *Proc. Fourth Int. Coral Reef Symp.* **1**:575-579.

Rosov, B., 2003, Sea Stewards: a volunteer ecological monitoring program. **In**: U.S. Department of Commerce, *Sanctuary Monitoring Report 2001: An Ecosystem Report Card*. Florida Keys National Marine Sanctuary, Marathon, FL, pp.51-53. [floridakeys.noaa.gov/research_monitoring/]

Shinn, E.A., B.H. Lidz, R.B. Halley, J.H. Hudson, and J.L. Kindinger, 1989, *Reefs of Florida and the Dry Tortugas*, Field Trip Guidebook T176, American Geophysical Union, Washington, DC, 53pp.

Smith, R., T. Maher, and B. Leeworthy, 2002, Monitoring use patterns surrounding sites for new artificial reefs. **In**: U.S. Department of Commerce, *Sanctuary Monitoring Report 2000*. Florida Keys National Marine Sanctuary, Marathon, FL, p.51. [floridakeys.noaa.gov/research_monitoring/welcome.html]

Starck, W.A., 1968, A list of fishes of Alligator Reef, Florida with comments on the nature of the Florida reef fish fauna, *Undersea Biology* **1**:4-40.

U.S. Department of Commerce (U.S. DOC), 1996, *Strategy for Stewardship: Florida Keys National Marine Sanctuary Final Management Plan/Environmental Impact Statement, 3 volumes*, Florida Keys National Marine Sanctuary, Marathon, FL.

Wheaton, J., W.C. Jaap, K. Hackett, M. Lybolt, M.K. Callahan, J. Kidney, S. Kupfner, J.W. Porter, V. Kosmynin, C. Tsokos, and G. Yanev, 2003, U.S. EPA/FKNMS coral reef monitoring project, **In**: U.S. Department of Commerce. *Sanctuary Monitoring Report 2001: An Ecosystem Report Card*, Florida Keys National Marine Sanctuary, Marathon, FL, pp.24-33. [floridakeys.noaa.gov/research_monitoring/]